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[Valovoye sodержaniye urana, radiya i toriya
v nekotorykh pochvoobrazuyushchikh porodakh]

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BULK CONTENT OF URANIUM, RADIUM, AND THORIUM
IN CERTAIN PARENT ROCKS

The content of natural radioactive elements in soils can be determined from their concentrations in the parent rocks from which the soils inherit the mineralogical and chemical composition. Obtaining information on the content of natural radioactive elements in parent rocks therefore is the most important feature of research in the characteristics of the ecological factor of natural radioactivity, and of the work involved in compiling maps and schematic maps showing the content of natural radioactive elements in soils.

Data on the natural radioactive elements are reviewed in a profile of a soil-geographic division of the Komi ASSR (Belyayev et al., 1960), in modern alluvial, ancient alluvial, and glaciofluvial deposits, blanket and moraine loams, and in eluvial-deluvial deposits of the Dvina, low-mountain Timan, Pechora, and mountainous Ural soil provinces.* In addition, change in the content of natural radioactive elements in certain deposits that form under the influence of the outpouring of waters with elevated contents of natural radioactive elements onto an old surface is traced.

Uranium was determined by luminescent (Markov, 1960), radium by emanation (Starik, Shchepot'yeva, 1961), and thorium by photocolormetric with arsenazo-Sh (Polyakov, Volynets, 1961) methods.

*We are very grateful to L. A. Verkholtantseva and V. A. Popov for their courtesy in placing at our disposal soil samples from their Pechora region collection.

Alluvial deposits. We examined the deposits from a near-fluvial flood plain. These deposits bear a resemblance, in terms of the qualitative composition of their constituent minerals, to the moraine deposits of a watershed (Stenina, 1952), and, because of the specifics of their formation, can be characterized as having a high content of sandy fractions and a small quantity of clayey particles, and as a result, a low content of sesquioxides and a high content of silicon oxide.

The absorption capacity, calculated per 100 g of clay, shows that secondary minerals of the montmorillonite group predominate in the colloidal fraction.

The content of natural radioactive elements in the deposits stipulated can be looked at from two aspects. The first of these is the provincial aspect, when these deposits are formed in various soil-geographic provinces (Dvina and low-mountain Timan), the second is that which takes into consideration change in the content of natural radioactive elements attributable to the outpouring of waters containing increased quantities of radium onto the day surface.

These deposits can have a broad range of thorium-uranium ratios (Table 1), and the radioactive equilibrium between radium and uranium can tilt in favor of excess radium.

The alluvial deposits (Table 1) contain uranium and radium in Clarke magnitudes that are less than those cited by Vinogradov (1957) for the lithosphere. It has been found that there is a tendency for the quantity of uranium in the Timan low-mountain province to increase with respect to the quantity in the alluvial deposits of the Dvina province.

The quantity of thorium in the alluvium of the Timan soil province

Table 1. CONTENT OF NATURAL RADIOACTIVE ELEMENTS IN PARENT ROCKS

Deposits	Soil provinces	Genetic horizon	U, 10 ⁻⁴ %	Th/U	Ra, p. 10 ⁻¹⁰ %	Ra/U p. 10 ⁻⁷ %	Ra/U, in % of equilibrium	Th, p. 10 ⁻⁴ %
Modern alluvial	Dvina	"A" ^x	0.33	56	0.84	25	.655	1.5 ^{xxx}
	Timan low-mountain	"A"	$\frac{1.20-2.37}{1.64}$	$\frac{8-15}{11}$	$\frac{0.69-1.25}{0.88}$	$\frac{5-6}{5}$	$\frac{.52-(.69)}{.58}$	$\frac{12.2-20.6}{17.3}$
		"B" ^{xx}	$\frac{0.31-2.52}{1.67}$	$\frac{5-29}{13}$	$\frac{0.44-2570.0}{695.93}$	$\frac{8-10198}{2603}$	$\frac{.147-(.3034238)}{.759352}$	$\frac{13.7-18.0}{15.8}$
Ancient alluvial	Dvina	"A"	0.42	24	0.23	5	.63	10.0
Glaciofluvial	Timan low-mountain	"A"	0.79	-	0.43	5	.60	-
		"A"	0.50	12	0.57	11	.239	5.8
Blanket	Dvina	"A"	0.92	5	0.65	7	.108	5.1 ^{xxx}
	Timan low-mountain	"A"	$\frac{0.65-1.20}{0.92}$	$\frac{4-17}{10}$	$\frac{0.65-0.70}{0.67}$	$\frac{6-12}{9}$	$\frac{.72-(.266)}{.169}$	$\frac{21-24}{23}$
		"B"	1.29	9	5.38	43	.1173	11.1
Moraine	Timan	"A"	$\frac{0.56-1.74}{1.15}$	$\frac{8-16}{12}$	$\frac{1.00-1.05}{1.02}$	$\frac{9-19}{14}$	$\frac{.183-(.456)}{.318}$	$\frac{8.7-12.6}{10.6}$
		"B"	1.28	12	2.75	21	.539	16.0
	Pechora	"A"	$\frac{0.70-1.24}{1.01}$	$\frac{6-11}{7}$	$\frac{0.19-0.69}{0.49}$	$\frac{3-6}{5}$	$\frac{-.19-(.63)}{.42}$	$\frac{4.7-11.0}{8.3}$

x "A" - Soils with a geochemical background of natural radioactive element content.

xx "B" - Soils that form under the influence of outpourings of waters with an elevated content of natural radioactive elements onto the day surface.

xxx - Obtained from calculations in terms of content in individual mechanical fractions.

is greater than that in the geochemical background of the lithosphere by a factor of 2. This is so because the watershed encompasses the Timanskiy Kryazh [Range], the bedrock of which is enriched with minerals of the thorium group. The data cited suggest the possibility of separating Timan into an independent geochemical province.

Radium is concentrated in the upper part of the soil profile when there is an outpouring of waters containing an increased quantity of radium onto the surface of what are normally wet flood-plain soils. Special exceptions to this rule are the flood-plain soddy-gley soils of the meso-depressions where a wash-water regime has prevailed for a long time, the result of the stagnation of melt waters and atmospheric precipitation, so what is observed is a tendency for the radium to shift from its original concentration site to a lower layer of the alluvial deposits, with subsequent entry into the ground water.

The ancient alluvial deposits, when looked at in terms of granulometric composition, are unconsolidated sands with a high content of SiO_2 , and minor quantities of sesquioxides.

When the spectra of the mechanical compositions of alluvial and ancient alluvial deposits are similar, the latter can be characterized as having a reduced content of sesquioxides and a low silt absorption capacity.

Ancient alluvial deposits will contain uranium that is less by a factor of 4-7, and radium that is less by a factor of 2-3.5, than the contents of these elements taken by Clarke for the lithosphere. The thorium content is somewhat in excess of the Clarke magnitude. The quantity of radium in the deposits from the Dvina province that were examined matches the content of radium obtained for dune deposits from Estonia (Baranov,

Morozova, et al., 1966). An increase in the content of uranium, radium, and thorium in the Timan province, as compared to that found in the Dvina province, is noted when the provincial aspect is taken into consideration; that is, the same trend that has developed for modern alluvial deposits is seen here as well.

The absolute magnitudes of uranium and radium contents in the ancient alluvial deposits in the Dvina and Timan provinces are lower than their contents in the alluvial deposits in these same regions. The trend that has been noted is directly associated with the low absorption capacity and the reduction in the content of sesquioxides.

The thorium/uranium ratio in the ancient alluvial deposits varies over quite a broad range, and the absolute values of these ratios are close to the ratios cited for the alluvial deposits. The deposits that have been examined show a disturbance in the radioactive equilibrium between radium and uranium that tends to the excess radium side (1-60%).

Glaciofluvial deposits. These are the deposits of the frontal, or morainal aprons of the marginal facies of the waning glacier. They are unconsolidated and consolidated sands in terms of mechanical composition. These sands, as distinguished from the alluvial and ancient alluvial deposits, can be characterized by a reduced content of silicon oxide, and by an increase in the quantity of sesquioxides.

The content of uranium and radium (Table 1) is lower, and the content of thorium is somewhat higher, than the corresponding Clarke values in the lithosphere. A trend to an increase in the content of uranium, thorium, and humus, along with a reduction in the diameter of the fractions, can be found in individual mechanical fractions.

Blanket deposits. These deposits are, in their genesis, secondary lithologic derivatives of a moraine (Gerasimov, Shchukevich, 1939). Characteristic of these deposits is a relatively increased content of clay fractions in the predominant background of the coarse silty part of the spectrum. The secondary minerals, judging from the absorption capacity, represent the montmorillonite and beidellite group (Zaboyeva, 1958; Rubtsov, 1968).

The quantity of uranium and radium found in the blanket deposits of the Dvina soil province (Table 1) is lower, but the thorium content is higher by a factor of 2, than the accepted geochemical background for the lithosphere.

A common property of the blanket loams therefore is a reduced content of uranium and an increased content of thorium. The increase in the quantity of thorium is much greater in the Timan province than it is in the deposits of the Dvina province.

Outpourings of waters containing an increased quantity of radium onto the surface are, for the most part, sorbed into the upper part of the soil profile. Nevertheless, the radium concentration in the BC-horizon is 5.38×10^{-10} percent; that is, in excess of the Clarke value for the lithosphere by a factor of almost 6. What follows, therefore, is that in the event of a wash-water regime, and good filtering capability on the part of the clayey loams, the more mobile natural radioactive elements, such as radium, for example, will migrate slowly, and in small quantities, into the deep horizons of the soil profile.

Moraine deposits can be characterized by a reduction in the sand part of the spectrum in the predominant coarse clayey background, and the result

will be an increase in the content, and a reduction in the quantity, of sesquioxides. The absorption capacity of the clay is 70 mg-equiv per 100 g, and this corresponds to the absorption capacity of minerals in the montmorillonite and beidellite group.

The quantity of uranium in the moraine deposits of the Timan and Pechora provinces is lower than that found in the geochemical background of the lithosphere (Table 1). The quantity of radium in the moraine deposits of the Timan province is somewhat higher than, and that in the moraine of the Pechora depression is half the Clarke magnitude for the lithosphere. The content of radium and thorium in the moraine deposits of the Pechora depression almost coincides with the content of these minerals in the uncarbonated moraine of Estonia (Baranov, Morozova, et al., 1966; Morozova, 1966). The thorium content in the moraine of the Pechora depression is close to that of the geochemical background, and is higher than the Clarke for the lithosphere by a factor of almost 1.5 in the Timan moraine.

The thorium-uranium ratio for the Timan moraine is higher than it is in the same kinds of deposits in the Pechora province. This is so because of the increase in the content of thorium in the Timan moraine deposits. The radium-uranium balance shows an excess of radium, and this shift is maximum in the Timan deposits, and minimum in the Pechora moraine.

The outpouring onto the soil surface of waters with a high radium content (Table 1) reveals that radium is sorbed into the upper part of the soil profile, for the most part. Fifteen to 20 years after the outpouring of waters onto the soil surface has ceased the quantity of radium found in the parent rock zone is greater than the radium content found in background sections by a factor of 3. This confirms the assumption that radium

migrates from the zone of initial accumulation, albeit in small quantities, given conditions of a wash-water regime.

Uranium, radium, and thorium are contained in all mechanical fractions of moraine deposits. There is a trend toward a relative accumulation of uranium and thorium in the clayey fraction (< 0.001 mm).

Eluvial-deluvial deposits of bedrock. The eluvial-deluvial deposits in the Timan soil-geographic province are products of the weathering of old rocks. These deposits are light and medium loams, in terms of their mechanical composition, with large silty particles predominant in the background of an increased quantity of clayey fractions. These can be characterized as having a relatively increased content of SiO_2 , and a decreased quantity of R_2O_3 , for a low absorption capacity.

The quantity of radium in these deposits fluctuates at the level of the geochemical background of the lithosphere, while that of uranium is somewhat lower than the background (Table 2).

The quantity of thorium in those sections that have not been disturbed by tectonic phenomena exceeds the Clarke for the lithosphere by a factor of 4-5, as a mean, and the content can exceed that of the geochemical background by a factor of 13-15, as a mean, at sites of tectonic disturbances.

The thorium-uranium ratio (Table 2) varies from 8 to 200, but the maximum noted in eluvial-deluvial deposits of a zone of tectonic faults, and the minimum noted in the deposits, have not been subjected to these phenomena.

The balance between radium and uranium in these particular deposits tilts to the side of an excess of radium. Characteristically, the shift in the equilibrium toward an excess of radium is even sharper in soils

forming in these deposits. This is associated with the greater biological mobility of the radium, on the one hand, and by the evacuation of the movable forms of uranium under the conditions prevailing in a wash-water regime, on the other.

Uranium, radium, and thorium are contained in all mechanical fractions. A comparison of the eluvial-deluvial deposits in the landscape plan reveals that the quantity of physical clay in the deposits increases from the mountain-tundra (5-14%) to the mountain-forest belt (20-40%), and this is the result of nonuniformity in the processes of physical and physico-chemical weathering and soil formation within the limits of the vertical zonality. The relative content (in %, with % of fraction taken into consideration) of uranium, radium, and thorium in a fraction of physical clay changes from 11-20% to 50% in this same direction.

The quantity of uranium in the fine earth of the eluvial-deluvial deposits of the Northern Urals with a light mechanical composition is greater than that in the geochemical background of the lithosphere by a factor of 2, as a mean, while that of radium is greater by a factor of 3, and that of thorium by a factor of 1.5. The absolute content of uranium and thorium in the sands and sandy loams (Table 2) is greater than that in the medium and heavy loamy deposits. On the other hand, there are larger quantities of radium in the eluvial-deluvial deposits with a loamy mechanical composition. The nature of the change in the content of uranium and thorium from light rocks to heavier ones does not concord with the data cited by Baranov, V. I., Morozova, N. G., et al. (1966), for moraine deposits. A like discordance finds its explanation in the anomaly content of natural radioactive elements, and in the richness of their primary minerals as compared

Table 2. CONTENT OF NATURAL RADIOACTIVE ELEMENTS IN ELUVIAL-DELUVIAL DEPOSITS (in fine earth, particles < 1 mm, per calcined weighed batch).

Soil province	No. sections	Horizon	U, p.10 ⁻⁴ %	Th/U	Ra, p.10 ⁻¹⁰ %	Ra/U p.10 ⁻⁷ %	Ra/U, in % of equilibrium	Th, p.10 ⁻⁴ %
Timan low-mountain	9	BC	$\frac{1.12-3.16^x}{2.28}$	$\frac{8-201}{46}$	$\frac{0.68-1.24}{0.99}$	$\frac{2-9}{5}$	$\frac{-26-(+87)}{+23}$	$\frac{19.0-427.0}{93.8}$
Northern Urals	10	BC	$\frac{2.94-9.00}{5.19}$	$\frac{1-4}{3}$	$\frac{1.32-6.64}{2.91}$	$\frac{3-9}{5}$	$\frac{-13-(+183)}{+59}$	$\frac{10.0-27.3}{14.5}$
Polar Urals	5	BC	$\frac{1.16-13.0}{5.35}$	$\frac{4-104}{45}$	$\frac{0.75-10.4}{4.54}$	$\frac{3-22}{9}$	$\frac{-1-(+557)}{+157}$	$\frac{23.0-230.0}{116.0}$

x - Variations are shown in the numerator, the mean arithmetic value of the variations in the denominator.

to the moraine, as a result of which the various aspects of the chemical properties of uranium and thorium appeared when there was a predominance of physical, or physicochemical, weathering in the different bioclimatic zones.

Examination of the content of natural radioactive elements in the landscape aspect permits making the following comments:

1. the eluvial-deluvial deposits of the Northern Urals contain an elevated content of natural radioactive elements with respect to the geochemical background of the lithosphere; uranium by a factor of 1.5-2, radium by a factor of 3-4, and thorium by a factor of 1.5-2.5, so that an anomaly content of natural radioactive elements is characteristic of this particular territory;

2. the relative content of natural radioactive elements in a fraction of physical clay of the eluvial-deluvial deposits in the mountain-tundra and mountain-forest landscape belts has a zonal character; that is, there is a corresponding increase in the content of natural radioactive elements with an increase in the fraction of physical clay from the mountain-tundra to the mountain-forest soils.

The eluvial-deluvial deposits of the Polar and Northern Urals can be compared on a regional basis. The eluvial-deluvial deposits of the Polar Urals are products of the weathering of metamorphic rocks that are for the most part chlorite-sericite, quartz-sericite-chlorite, and other schists. In terms of mechanical composition, these are loamy sands and light loams.

The absolute content of uranium, radium, and thorium (Table 2) is close to that found in similar deposits in the Northern Urals, and also exceeds the geochemical background of the lithosphere in terms of uranium by a

factor of 1.5, and of radium by a factor of 5. The content of thorium is greater than the Clarke for the lithosphere by a factor of 20, as a mean. The eluvial-deluvial deposits of the Polar Urals therefore have a multicomponent composition of natural radioactive elements, although thorium has the leading role.

The Northern and Polar Urals are a geochemical region in terms of content of natural radioactive elements, but the individual sections comprising the region are not of equal importance in terms of content of those elements. It is possible, for example, to single out the Northern Urals, within the limits of the territory under consideration, as a geochemical area with an elevated content of uranium, radium, and thorium, whereas the Polar Urals can be singled out as a thorium geochemical area.

The radioactive equilibrium between radium and uranium is unbalanced in favor of radium in the eluvial-deluvial deposits of the Northern and Polar Urals. The excess of radium is even higher in soils that have formed from these deposits. The differences in shifts in equilibrium between deposits and soils that have been observed are associated with the special soil formation features.

There are natural radioactive elements in all the mechanical fractions of Urals eluvial-deluvial deposits. Uranium, radium, and thorium are contained for the most part in a fraction of physical sand in deposits with a light mechanical composition (sands, loamy sands) that are characteristic of the mountain-tundra zone. The greater part of the natural radioactive elements are associated with a fraction of physical clay in the loamy deposits of the mountain-forest zone.

A trend toward direct correlations between the content of organic matter and the natural radioactive elements in a fraction of clay can be noted in the fine earth of the eluvial-deluvial deposits; that is, the higher the humus content in the clay, the greater its radium, uranium, and thorium content.

In conclusion, it should be pointed out that in terms of natural radioactive element content, the alluvial and ancient alluvial deposits have features that are similar to those of deposits comprising the watershed. Hence the trend toward an increased thorium content for the Timan region.

The radium-uranium balance is tilted to the excess radium side in the alluvial and ancient alluvial deposits.

The blanket and moraine deposits in the Timan region are enriched with thorium, while the deposits in the Pechora depression contain thorium in quantities that are within the Clarke limits for the lithosphere.

Uranium, radium, and thorium are contained in all mechanical fractions of the deposits under review.

The eluvial-deluvial deposits of the Polar and Northern Urals contain uranium, radium, and thorium in quantities that are higher than the Clarke for the lithosphere; that is, the territory of the Urals can be equated to a region with a relatively high content of natural radioactive elements.

The content of natural radioactive elements in a fraction of physical clay can have zonal features.

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